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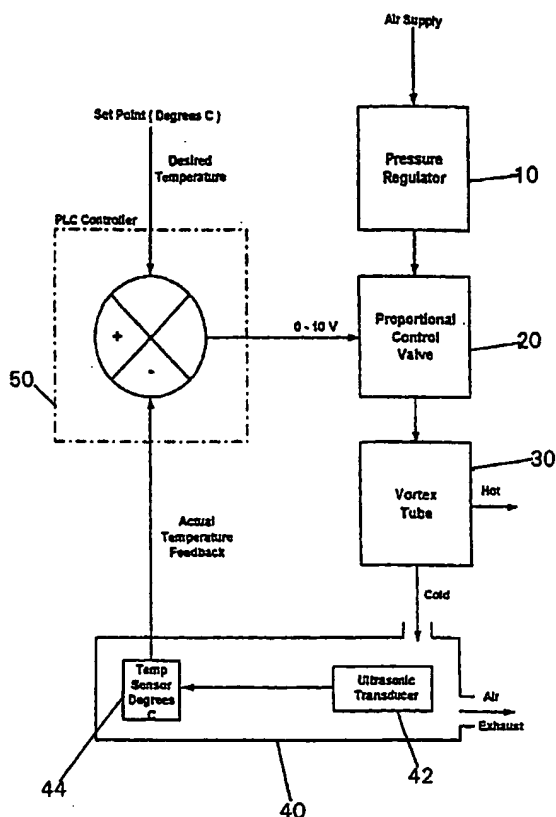
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(54) Title: APPARATUS FOR GENERATING ULTRASOUND



(57) Abstract: The present invention relates to apparatus for generating ultrasound, which comprises an ultrasound generator (40) and cooling means for cooling the ultrasound generator (40) by applying a cooling gas thereto, wherein the cooling means comprises a pressure regulator (10) for regulating pressure of a gas, a flow regulator (20) for regulating flow of the gas, and a gas fraction separator (30) for separating lower temperature and higher temperature fractions of the gas, wherein in use the lower temperature fraction is delivered to the ultrasound generator (40).

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- 1 -

APPARATUS FOR GENERATING ULTRASOUND

The present invention provides apparatus for generating ultrasound, in particular apparatus for generating ultrasound
5 which comprises an ultrasound generator and means for cooling the ultrasound generator.

The term "ultrasound" is commonly used to refer to sound energy having a frequency above 20 kHz, i.e. frequencies
10 higher than those normally audible to humans. Ultrasound is conventionally generated by a transducer, which converts mechanical or electrical energy into ultrasonic vibrations, and transmitted to the desired medium, typically via a horn or probe. Most conventional ultrasonic transducers are
15 designed to deliver frequencies in the range from 20 to 35 kHz. Transducers operating below 20 kHz can be excessively noisy, whereas reductions in power delivery can occur above 35 kHz.

20 The industrial uses of ultrasound are varied and well known, for example, welding, cutting, atomisation, cleaning and decontamination, and industrial processing.

As referred to above, apparatus for generating ultrasound
25 typically comprises a transducer and a horn or probe. Additional components commonly referred to as boosters and extenders are often used with the transducer and horn or probe. The booster and/or extender are typically used to modulate the amplification of ultrasonic vibration at the face
30 of the horn or probe, e.g. the booster and/or extender may be used to increase or decrease the vibrational energy emitted at the face of the horn or probe. The term "ultrasonic stack" is conventionally used in the art to describe apparatus for

- 2 -

generating ultrasound which comprises a transducer, booster, extender, and horn or probe combination. The transducer passes vibrations through the booster and extender to the horn or probe, and thus into the desired medium.

5

Ultrasonic transducers produce large amounts of heat energy during operation, and are typically cooled in conventional stacks by convection currents which draw ambient air over the transducer surface. However, such conventional cooling methods
10 are difficult to control, and can result in the stack operating other than at optimum temperature with consequent reduction in efficiency.

If the ultrasonic stack is operated for short time periods,
15 e.g. fractions of a second, then a lack of cooling control may not be detrimental to stack efficiency. For example, fans may direct air from unregulated air lines towards the transducer heat sinks to ensure reliable operation without risk of overheating.

20

However, industrial ultrasound applications are increasingly requiring continuous stack operation. Transducer cooling is critical to ensure operational efficiency and reliability. The aforementioned conventional cooling methods of passing air
25 over the transducer heat sinks typically either provide insufficient cooling for a continuously operating stack, or are prohibitively expensive.

The present invention seeks to overcome the abovementioned
30 drawbacks of conventional apparatus for generating ultrasound.

According to the present invention there is provided apparatus for generating ultrasound, which comprises an ultrasound

- 3 -

generator and cooling means for cooling the ultrasound generator by applying a cooling gas thereto, wherein the cooling means comprises a pressure regulator for regulating pressure of a gas, a flow regulator for regulating flow of the
5 gas, and a gas fraction separator for separating lower temperature and higher temperature fractions of the gas, wherein in use the lower temperature fraction is delivered to the ultrasound generator.

10 The apparatus of the present invention thus comprises an ultrasound generator and cooling means therefor. The ultrasound generator may be any conventional ultrasound stack, as referred to hereinabove, comprising a transducer, booster, extender, and horn or probe combination. Such stacks are well
15 known to those skilled in the art, and do not require further description.

The cooling means of the apparatus of the present invention comprises a pressure regulator for regulating pressure of a
20 gas, a flow regulator for regulating flow of the gas, and a gas fraction separator for separating lower temperature and higher temperature fractions of the gas, wherein in use the lower temperature fraction is applied to the ultrasound generator. The cooling means allows for cooling gas to be
25 delivered to the ultrasound generator, preferably the transducer, in regulated quantities according to the particular requirements of the apparatus under operation. These requirements will depend, for example, upon the application for which the apparatus is being used, the
30 particular booster and extender being used, and the mode of operation.

The pressure regulator regulates the pressure of gas entering

- 4 -

the cooling means, and the flow regulator regulates the flow of the gas entering the gas fraction separator. On entering the gas fraction separator, the gas is separated into lower temperature and higher temperature fractions, with the lower temperature fraction being delivered to the ultrasound generator, preferably the transducer, to cool the generator. The ultrasound generator preferably comprises a sensor for sensing the operating temperature of the ultrasound generator. In this way the actual operating temperature may be compared to the optimum operating temperature, and the flow regulator may be adjusted to increase or decrease the gas flow to the gas fraction separator, according to the difference between the actual and optimum operating temperatures.

15 The cooling means can preferably deliver cooling gas to the ultrasound generator at temperatures below ambient, more preferably at temperatures as low as -40°C . The gas is preferably air, and the quality of air delivered to the ultrasound generator by the cooling means preferably complies with air quality classification 1.4.1. according to ISO 8573.1. The maximum gas flow to the ultrasonic generator is preferably at least 25 lsec^{-1} , more preferably at least 50 lsec^{-1} , for example substantially 55 lsec^{-1} . The maximum pressure of gas directed to the ultrasound generator is 25 preferably at least $5.0 \times 10^5 \text{ Nm}^{-2}$, for example substantially $7.5 \times 10^5 \text{ Nm}^{-2}$.

The pressure regulator may comprise any regulator by which the pressure of gas entering the flow regulator may be regulated. 30 A preferred pressure regulator is a pneumatic control valve, for example a pneumatic control valve having a maximum pressure rating of at least $1 \times 10^6 \text{ Nm}^{-2}$ (e.g. substantially $2 \times 10^6 \text{ Nm}^{-2}$).

- 5 -

Gas from the pressure regulator enters the flow regulator. The flow regulator may comprise any regulator by which the flow of gas entering the fraction separator may be regulated. A preferred flow regulator is a control valve, more preferably
5 a pneumatic proportional valve. The pneumatic proportional valve is preferably controlled by a Proportional, Integral, Derivative (PID) loop, which feeds back information detected by sensors regarding the operating temperature of the ultrasound generator to a controller, which adjusts the
10 pneumatic proportional valve accordingly.

Gas from the flow regulator enters the gas fraction separator. A preferred gas fraction separator is a vortex tube which separates the gas into a higher temperature fraction and a
15 lower temperature fraction. The lower temperature fraction is directed to cool the ultrasound generator, and the higher temperature gas is expelled. The vortex tube preferably has a maximum gas flow capacity of at least 10 lsec^{-1} , for example substantially 16.5 lsec^{-1} , and an inlet working pressure of at
20 least $5 \times 10^5 \text{ Nm}^{-2}$, for example substantially $8 \times 10^5 \text{ Nm}^{-2}$.

According to the present invention there is also provided a method for cooling an ultrasound generator by applying a cooling gas thereto, which method comprises passing a gas into
25 a pressure regulator to regulate pressure of the gas, allowing gas to pass from the pressure regulator into a flow regulator for regulating flow of the gas, allowing the gas to pass from the flow regulator into a gas fraction separator to separate lower temperature and higher temperature fractions of the gas,
30 and allowing the lower temperature fraction of the gas to be delivered to the ultrasound generator.

According to the present invention there is further provided

- 6 -

use of a vortex tube for cooling an ultrasound generator by separating lower temperature fractions from higher temperature fractions of a gas entering the vortex tube, and allowing the lower temperature fraction to be delivered to the ultrasound generator for cooling the ultrasound generator.

A preferred embodiment of the present invention will now be described in detail by way of example with reference to accompanying Figure 1, which is a flow chart illustrating the steps of an embodiment of the method of the present invention.

Referring to Figure 1, apparatus for generating ultrasound comprises a pressure regulator 10, a proportional control valve 20, a vortex tube 30, an ultrasound generator 40, and a controller 50. The ultrasound generator 40 comprises an ultrasonic transducer 42 and a temperature sensor 44.

The pressure regulator 10 is a pneumatic control valve having a preferred maximum pressure rating of $2 \times 10^6 \text{ Nm}^{-2}$. Air is passed into the pressure regulator 10 from an air supply, and the pressure regulator 10 reduces the pressure of the upstream air from the air supply to a predetermined desired downstream pressure.

The air leaving the pressure regulator 10 at the predetermined pressure is passed into a proportional control valve 20, which regulates air flow. A particularly preferred proportional control valve 20 is a Sentronic valve from Asco Joucomatic Limited. The pneumatic proportional valve 20 is controlled by a PID loop, in which temperature readings from the sensor 44 are fed back to the controller 50, which adjusts the pneumatic proportional valve 20 accordingly for optimum operation of the ultrasound generator 40.

- 7 -

Air from the pneumatic proportional valve 20 enters the vortex tube 30, which separates the air into lower and higher temperature fractions. Any suitable vortex tube 30 may be used, although preferred vortex tubes 30 are available from
5 Meech Air-Tec Limited. The lower temperature fraction of the air is delivered from the vortex tube 30 to the ultrasound transducer 42 of the ultrasound generator 40, and may have a temperature as low as -40°C.

10 The sensor 44 senses the temperature of the ultrasound generator 40, in particular the ultrasound transducer 42, and feeds this information back to the controller 50. The controller 50 compares the actual operating temperature of the ultrasonic generator 40 as measured by the sensor 44 with the
15 optimum operating temperature of the ultrasonic generator 40, and adjusts the proportional valve control 20 accordingly to increase or decrease the air flow to the vortex tube 30.

In this way, in the apparatus of the present invention the
20 temperature of the ultrasonic generator can be constantly monitored and maintained at a desired level for optimum efficiency.

It will be understood that the embodiment illustrated shows
25 one application of the invention only for the purposes of illustration. In practice the invention may be applied to many different configurations, the detailed embodiments being straightforward for those skilled in the art to implement.

- 8 -

CLAIMS

1. Apparatus for generating ultrasound, which comprises an ultrasound generator and cooling means for cooling the
5 ultrasound generator by applying a cooling gas thereto, wherein the cooling means comprises a pressure regulator for regulating pressure of a gas, a flow regulator for regulating flow of the gas, and a gas fraction separator for separating lower temperature and higher temperature fractions of the gas,
10 wherein in use the lower temperature fraction is delivered to the ultrasound generator.
2. Apparatus according to claim 1 wherein the pressure regulator comprises a pneumatic control valve.
15
3. Apparatus according to claim 1 or 2 wherein the pressure regulator has a maximum pressure rating of at least $1 \times 10^6 \text{ Nm}^{-2}$.
20
4. Apparatus according to any one of claims 1 to 3 wherein the flow regulator comprises a control valve.
5. Apparatus according to claim 4 wherein the control valve is a pneumatic proportional valve.
25
6. Apparatus according to any preceding claim wherein the gas fraction separator is a vortex tube.
7. Apparatus according to claim 6 wherein the vortex tube
30 has a maximum gas flow capacity of at least 10 lsec^{-1} and/or an inlet working pressure of at least $5 \times 10^5 \text{ Nm}^{-2}$.
8. Apparatus according to any preceding claim 1 wherein the

- 9 -

ultrasound generator further comprises a sensor for sensing the operating temperature of the ultrasound generator.

9. Apparatus according to claim 8 which further comprises
5 a controller for controlling the flow regulator according to information provided to the controller by the sensor.

10. Apparatus according to claim 8 or 9 which further comprises a PID loop.

10

11. A method of cooling an ultrasound generator by applying a cooling gas thereto, which method comprises passing a gas into a pressure regulator to regulate pressure of the gas, allowing gas to pass from the pressure regulator into a flow
15 regulator for regulating flow of the gas, allowing gas to pass from the flow regulator into a gas fraction separator to separate lower temperature and higher temperature fractions of the gas, and allowing the lower temperature fraction of the gas to be delivered to the ultrasound generator.

20

12. A method according to claim 11 wherein the lower temperature fraction has a temperature of between ambient and -40°C.

25 13. A method according to claims 11 or 12 wherein the gas is air.

14. A method according to claim 13 wherein the lower temperature fraction complies with air quality classification
30 1.4.1. according to ISO 8573.1.

15. A method according to any one of claims 11 to 14 wherein the maximum gas flow to the ultrasound generator is at least

- 10 -

25 lsec^{-1} .

16. A method according to claim 15 wherein the maximum gas flow to the ultrasound generator is at least 50 lsec^{-1} .

5

17. A method according to any one of claims 11 to 16 wherein the maximum pressure of gas directed to the ultrasound generator is at least $5.0 \times 10^5 \text{ Nm}^{-2}$.

10 18. Use of a gas fraction separator for cooling an ultrasound generator by separating lower temperature fractions from higher temperature fractions of a gas entering the gas fraction separator, and allowing the lower temperature fraction to be delivered to the ultrasound generator for
15 cooling the ultrasound generator.

19. Use of a gas fraction separator according to claim 18 wherein the gas fraction separator is a vortex tube.

20 19. Apparatus for generating ultrasound substantially as hereinbefore described.

20. A method for cooling an ultrasound generator substantially as hereinbefore described with reference to the
25 accompanying drawing.

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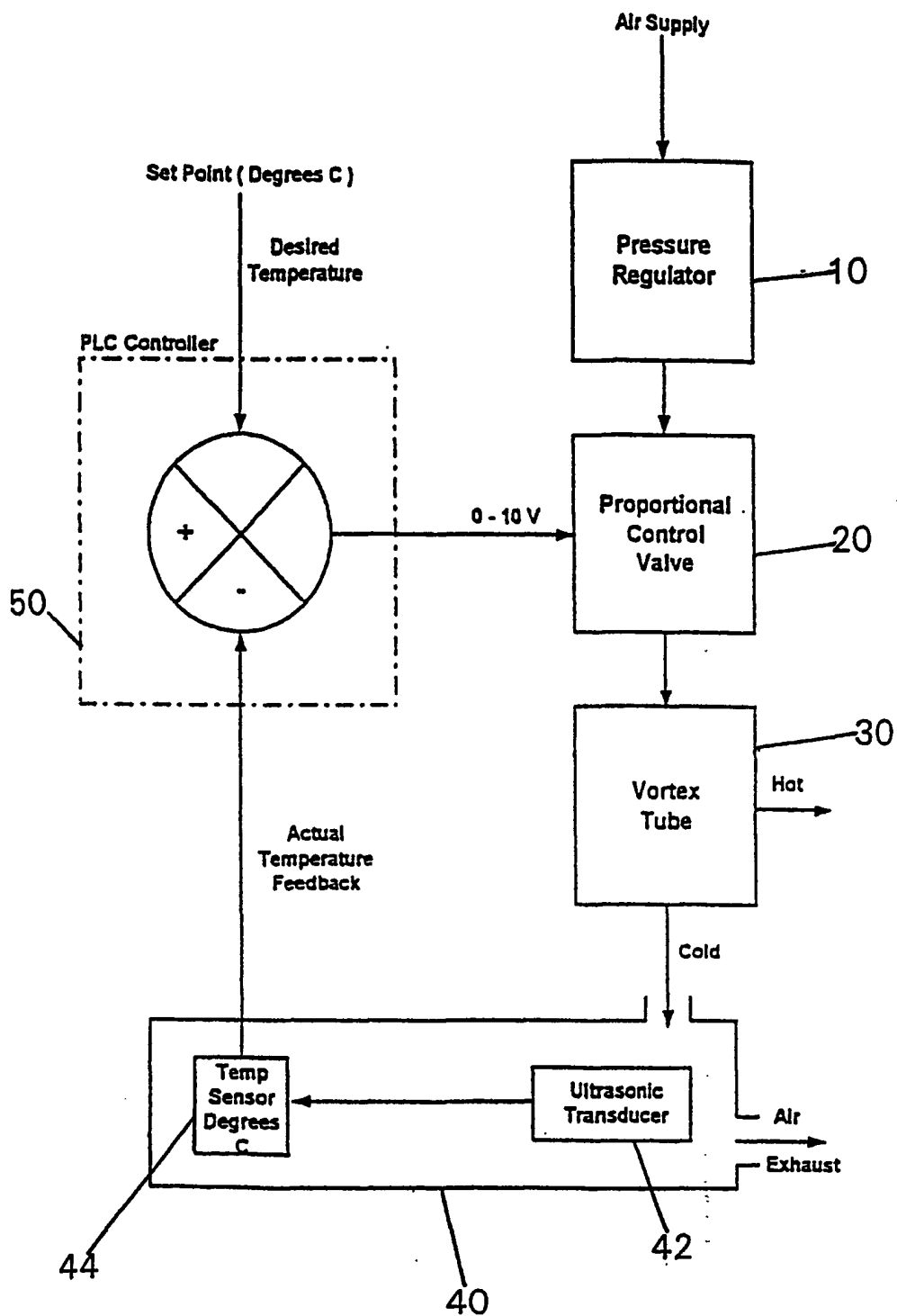


Figure 1

INTERNATIONAL SEARCH REPORT

Internat Application No

PCT/GB 02/04938

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F25B9/04 G10K15/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 19, 5 June 2001 (2001-06-05) & JP 2001 037800 A (TOSHIBA CORP), 13 February 2001 (2001-02-13) abstract	1,2,4-6, 8,9,11, 12,18,19
Y	WO 01 29491 A (MOLINAR LTD (GB); GEE PETER JOHN (GB) ET AL.) 26 April 2001 (2001-04-26) page 10, paragraph 2 -page 12, paragraph 3; figures 1,2	1,2,4-6, 8,9,11, 12,18,19
A	US 5 682 749 A (BRISTOW DUNCAN J ET AL) 4 November 1997 (1997-11-04) column 3, line 32 -column 5, line 65; figure 1	1,4-6, 8-11,18, 19
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the International search

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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